

sun-spot maximum centering about 1860, 1870, 1883, 1894, and 1906 and computed the annual rainfall departure for the central year and the single year immediately preceding and following; thus the years 1859, 1860, and 1861 would represent the epoch of spot maximum of 1860. Four out of the five epochs were, on the average, periods of more than normal rainfall and but one, that of 1894, was a time of deficient precipitation. Casual inspection of the precipitation record for Berlin discloses the fact

that in the 60 years 1848-1907 there were more wet than dry years, a condition directly contrary to that which is the rule in the United States, but whether this condition is common to northern Europe is not at this time known.

The concluding chapters of Dr. Douglass's work are devoted to a discussion of "Methods of Periodic Analysis," "Cycles" with an appendix giving tables of mean tree growth extending back to 1306 B. C. The book should be read by all students of weather periodicities.

CLEMENTS ON DROUTH PERIODS AND CLIMATIC CYCLES.¹

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Dr. Clements refers briefly to the work of Douglass² in relating the annual rings of trees to rainfall and the sun-spot cycle as suggesting the possibility of using the latter for forecasting the rainfall from year to year.

He also adds, seemingly in confirmation of Douglass's work, the statement that "practically all the groups of trees studied gave a clear record of growth cycles corresponding closely to the sun-spot cycle. They confirmed the hypothesis that years of sun-spot maxima were generally marked by deficient rainfall, and those of sun-spot minima by rainfall above the normal."

A preliminary examination of the rainfall records of the States west of the Mississippi River showed that the two major drouth periods of 1893-1895 and 1870-1873 coincided with sun-spot maxima. It was also evident that abundant precipitation had occurred frequently, if not regularly at times of sun-spot minima and from these facts the inference was drawn that the spot minimum of 1913 would be accompanied by an excess of rainfall and that the spot maximum of 1917 would likewise be associated with a deficit in the rainfall. Partial confirmation of these inferences led the author to make the following statements:³

The most attractive and promising feature of the summer's work has been the checking and tracing of the course of the present climatic cycle. The second recorded absolute minimum of no sun spots occurred in 1913 and served as the focus of a period of exceptional rainfall in the West. The drouth of the present summer (1916) in the Western and Mountain States suggests the beginning of the dry phase of the cycle. Its effect upon the carrying capacity of the ranges and upon the production of dry farms has been critical. Whether it be followed by the full period of several dry years or not, it has furnished further confirmation of the fact that all grazing and dry farming must be based upon the recurrence of dry periods; in both a scientific system of expansion and contraction must be devised to prevent disaster during dry years. If the next two or three years prove to be dry in harmony with the maximum of the sun-spot cycle, the possibility of anticipating dry seasons will be greatly enhanced. In the field of forestation much evidence has been obtained to show that planting is successful only during wet phases and that natural reproduction occurs practically only during such phases.

The investigations of climatic cycles has been continued from both the biological and astronomical approach. The former gains interest from the fact that the years 1916, 1917, and 1918 have in general been years of drouth in the West and especially the Southwest. This was suggested as a probability upon the approach of the sun-spot maximum in 1916. The maximum was passed in 1917 and attention is now centered upon the expected increase of rainfall generally as the sun-spot minimum is approached during the next four or five years. It is proposed to follow the biological effects as seen in growth, reproduction, and abundance as closely as possible and to correlate these with the climatic phases. Striking evidence of these effects have been obtained during the drouth of the past two years. By far the most important problem, however, is the relation of the sun-spot cycle to the climatic and growth cycles. There appears to be little question

of the usual coincidence of these three cycles, but the existence of a causal relation is still in doubt. In the endeavor to make use of the sun-spot cycle to anticipate climatic changes, this matter is of paramount importance.⁴

The remainder of the article is devoted to an examination of the rainfall records of 23 States west of the Mississippi in an effort to establish a basic relation between rainfall and the spottedness of the sun. The method of collating the rainfall records was as follows: In the 23 States there were 323 rainfall records in 1881 and more than 1,300 in 1919. For the seventies the number was less than 100—76 in 1869, and for earlier years still less. The yearly departures of the annual totals from the normal were tabulated and classed as positive or negative by years, or rather by groups of five years, the central year of each group being the year in which the epoch of maximum sun spots occurred. The groups, therefore, center about the years 1837, 1848, 1860, 1871, 1883, 1894, 1907, and 1917. Concerning these epochs of maximum, Doctor Clements further remarks:

Since the beginning of observations in 1750 the yearly number of sun spots at the maximum has varied from 46 to 154, though the number has fallen below 80 for but 5 of the 16 maxima. For the 8 maxima considered here, the number of spots falls below 80 only in 1907⁵ and 1883, when the numbers were 62 and 64, respectively. In other words, 6 of the maxima lie above 77; i. e., half the number of spots for the highest maximum, 154.

DISCUSSION.

The chief interest in Doctor Clements's paper is, of course, the coupling of the period of solar activity manifested in the spottedness of the sun with terrestrial rainfall and the endeavor to anticipate the character of the seasonal rainfall some years in advance. I shall therefore first consider the connection between the occurrence of sun spots and rainfall.

SUN-SPOT RAINFALL RELATIONS.

Since Meldrum, in 1872, called attention to the possible connection between the phenomena above mentioned, much discussion has arisen or, rather, many persuasive reasons have been adduced in support of the idea that there must be a basic connection between the two events. It is scarcely necessary to analyze the large literature on the subject already available, but it will be desirable to touch upon the several stages of the arguments which have been advanced in support of the hypothesis.

The effort to relate sun spots with terrestrial weather dates back many years, but the specific attempt to show a relation between sun spots and rainfall is of comparatively recent origin. The discovery of what is popularly

¹ *Ecology*, Vol. II, No. 3, July, 1921.

² *MO. WEATHER REV.* 37: 225-236 and abstract of a later work in this REVIEW, immediately preceding.

³ Carnegie Inst. Wash. Pub. No. 242, 1916.

⁴ Loc. cit., pub. 304, 1917.

⁵ According to Wolfer, the epoch of maximum at this time occurred in 1906.4, and the maximum number of spots was 64.2 (smoothed) in February. The epoch of 1883, according to the same authority, occurred 1883.9, and the maximum number of spots was 74.6 in November of that year.